

California's Graduated Driver Licensing Ten Years Later: Effects on Motor Vehicle Fatalities and Crashes through Age 25

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Abstract

California's 1998 Graduated Driver Licensing (GDL) law imposed complex restrictions, enhanced supervision, and delayed licensure on new drivers under age 18. While initial researchers credited GDL with reducing fatalities among 16-year-olds, later research found larger fatality increases among the 18- and 19 age group of GDL "graduates." This study uses Center for Health Statistics and Fatality Analysis Reporting System traffic data from 1996-2008 to conduct time-series analyses of the longer-term effects of California's GDL law on motor vehicle fatalities and fatal crashes among the 16-25 age group. The control series consisted of Californians in the 27-39 age group during the same time period who reached age 16 before GDL took effect.

The analysis found that from 1996-2008, the 16-25 age group subjected to GDL suffered significant net increases of 5% in drivers' fatal crash involvements and 7% in traffic fatalities compared to the control group not exposed to GDL. Declines in fatalities and fatal crashes among the 16-17 year old age group were more than offset by larger increases in fatalities and fatal crashes among ages 18-25. For the 16-25 age group as a whole, California's GDL was associated with approximately 60 more fatal crashes and fatalities per year. These results replicate and extend the negative findings regarding GDL. They suggest that lawmakers now should consider repealing or substantially modifying California's GDL in the direction of a more flexible, professional licensing system.

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Introduction

California's Graduated Driver Licensing (GDL) law was enacted in 1997 at a time when traffic crashes and deaths across the state, especially among teenagers, had fallen sharply and steadily to historic lows. A number of studies initially linked state GDL programs to reduced traffic fatalities among younger teenagers, leading many researchers to pronounce these laws an unqualified success (Insurance Institute for Highway Safety, 2012; Fell et al, 2011; Chen, Baker & Li, 2006; Morrissey, Grabowski, Dee & Campbell, 2006

California's new GDL law, effective July 1, 1998, remains among the most restrictive of all other states (California Department of Motor Vehicles 2013; Masten & Hagge, 2003). It

requires new drivers ages 16 or 17 to undergo a lengthy, two-stage licensing process involving driver training by a licensed driver age 25 or older, driver education, and multiple driver tests, and to observe bans on driving late at night and on transporting passengers under age 20 during the probationary period. California's GDL requirements are detailed in the Appendix.

Limitations in Previous Research

California's GDL program was associated in initial studies with reduced traffic fatalities among 16-year-olds (Chen, Baker, & Li, 2006; Cooper, Gillen & Atkins, 2004). However, more recent studies warn that GDL laws may have unintended consequences in terms of fatal crash increases among older teenagers (Masten, Foss, & Marshall, 2011; Males, 2007; Males, 2006; Masten & Hagge, 2003). Recent, longer-term

research has uncovered three major weaknesses with nearly all conventional studies that have claimed benefits from GDL and have served as the basis for policy recommendations:

- (1) Studies were limited to examining GDL effects only on 16- and occasionally 17-year olds but neglected to study ongoing effects on 18 and older age groups who had been exposed to GDL at ages 16-17.
- (2) Most studies employed 18, 18-19, or 18-20 year-olds as a control group supposedly unaffected by GDL. However, if GDL boosts traffic crash and fatality tolls among the 18-and-older control group, then the control group is affected by the law and, therefore, it is not a true control group. The result of using a control group that is negatively affected by GDL is that post-GDL traffic tolls among the 16-17 year-old test group would appear artificially lower in comparison.
- (3) Most studies were limited to examining only driver fatalities or fatal crash involvements, omitting GDL effects on fatalities among passengers and non-motorists.

To overcome these weaknesses in previous studies, it is important to evaluate the full range of impacts of GDL. By restricting 16-17 year-olds from obtaining independent driving experience (including driving alone, at night, and with peer passengers), the GDL forced teenagers to seek a variety of alternative driving arrangements (Males, 2006, 2007). These alternative arrangements included being driven as passengers by others and using non-motorized forms of transportation such as walking and bicycling. This altered experience can be seen in the sharply reduced numbers of drivers' licensees age 16 (down 39% as a percent of the 16 year-old population from 1997 to 2008) and 17 year-olds (down 15%); older ages showed increases (Federal Highway Administration, 2008).

Passenger and Non-Motorist Effects

Due to GDL restrictions, then, some teenagers would have suffered crashes and fatalities while

being transported by older drivers or using non-motorized transportation (Males, 2006, 2007). These risks can be measured. If GDL reduced driver crash risks without creating other risks, as past studies have assumed, we would expect to see motor vehicle fatalities and driver crash involvements falling among GDL-affected young people at roughly the same rate over time. However, this is not the case. The ratio of the number of fatalities to the number of driver fatal crash involvements for the 16-17 age group rose from 0.88 prior to GDL to 1.03 after GDL, but did not increase among older age groups not exposed to GDL (see Table 1). This indicates that either 16-17 year-old drivers' post-GDL crashes somehow became substantially "deadlier" (that is, resulted in more fatalities per crash), or that a substantially higher proportion of 16-17 year-olds suffered fatalities as passengers or as non-motorists. These fatalities would also be GDL-related events, even though past research examining driver crash involvements has excluded passenger and non-motorist fatalities and thereby exaggerated the benefits of GDL. Because the altered conditions imposed by GDL have fatality implications beyond those involving driver outcomes alone, traffic deaths are a considerably more inclusive measure to assess GDL's full impact.

Immigration Effects

Previous studies also have had difficulties addressing the influence of newly arrived immigrants from other states or countries on young-motorist traffic deaths. With regard to immigrants from other states, virtually all young motorists are now subjected to GDL laws across the county regardless of where they first drove. The relatively small numbers who waited until age 18 to learn to drive and obtain licenses in order to evade California's GDL also are affected by the law, albeit in different ways than the majority licensed under GDL.

If the GDL law were followed by an epidemic of resident fatalities involving recent immigrants, whether from other states or nations, this might raise concerns of a confounding influence on traffic tolls. However preliminary analyses show this does not appear to be the case. Of those state residents the 16-25 age group who died in traffic

crashes in 2008, 70% were born in California, a higher percentage than in 1996 (a pre-GDL year, 59%). Further, in 2008, 28% of drivers in the 16-25 age group that were involved in fatal crashes were unlicensed, compared to 29% in 2005, and 25% in 1996 (FARS, 2013). Thus, while GDL was followed by slightly higher rates of more illegal driving as suggested (Males, 2006), there appears no influx of young immigrants, either national or international, boosting California residents' post-GDL traffic accident and fatality toll.

An unknown percentage of those not born in the state immigrated to California before age 18 and would have been subjected to GDL. In addition, some of the remaining fraction who immigrated to California at ages 18-25 in the post-law period would be expected to suffer fatalities and fatal crashes, but not to a significantly different extent than the 18-25-year-olds age group who immigrated to California during the prelaw period. It appears from this analysis that the effects on overall fatality trends of a few tens of thousands of new, young-adult immigrant drivers in the post-GDL period is negligible in a state with 4.5 million 18-25-year-old residents..

Hypothesis

This paper examines a “bottom line” issue: are young California motorists more or less likely to suffer traffic crashes than their predecessors because of the GDL laws that apply to them? The study includes as the test series not only those 16- and 17-year-olds who were licensed under GDL, but those age 18 and older who have “graduated” from GDL, those who either drove without a license or delayed licensing until age 18 or older, and those who refrained from driving themselves as a result of GDL. The present study extends the analysis of the longer-term effects of GDL laws by including the 18 through 25 year old age group, from 1996 through 2008. The hypothesis of this study is that GDL hampers the 16-17 age group from obtaining independent, individualized driving skills at young ages, thereby increasing traffic risks among post-GDL drivers who must acquire these skills at older ages

Methods

Time Period

The time period chosen for this analysis is 1996 through 2008. The year 1996 is chosen as the study period's beginning point due to a serious confound that occurred during the early 1990s: the large drop in motor vehicle fatalities involving California residents born in other countries. The cause is not known, but it coincided with changes in immigration policy, including a 1994 law requiring those applying for a driver's license to provide their social security number. Among the 16-25 age group, the number of traffic deaths among state residents born in Mexico fell by 58% from 1990 to 1996, the year such fatalities stabilized. This was a much larger decline than occurred among California-born residents or among foreign-born older residents, introducing an age-biased confound for traffic statistics prior to 1996. The year 2008 is chosen as the endpoint of the study period because 10 years, though an arbitrary cutoff, seems a reasonable time period for a social policy such as the 1998 GDL law to demonstrate effects before they are subsumed by other factors affecting traffic risks. The major economic downturn and raised gasoline prices beginning in 2009 that coincided with plummeting driving and traffic deaths provides an additional reason to exclude years after 2008.

Database

The California Department of Health Services' Center for Health Statistics (2012), or CHS, provides detailed mortality statistics by year for 1996-2008 on the age, cause of death, date of birth, and residence of decedent for all deaths occurring within California or to California residents elsewhere. CHS vital statistics data taken from verified medical examiner death certificates are complete and consistent over time, with virtually no “unknowns” reported for age and residence. They also provide an injury date showing that 99.4% of traffic deaths occur within the year of the injury. Further, CHS tabulations identify the age of motor vehicle fatalities more than either the Fatality Analysis Reporting System (2013, or “FARS”) or the California Highway Patrol's Statewide Integrated Traffic Records System (2013, or “SWITRS”), two alternative data bases that provide both lower numbers and no reliable

mechanism for determining whether the decedents are California residents. Neither FARS nor SWITRS tabulations provide information on when an over-18 California driver or fatal crash victim arrived in the state, or where they were born. Further, unlike CHS, SWITRS provides no way to distinguish between resident and nonresident traffic events, nor does it capture California residents' traffic events occurring outside California. The final CHS data base includes 23,460 fatalities among California residents in the 16-39 age group for the 1996-2008 period.

Variables Selected from Database

Motor vehicle deaths (group codes 296 through 306, International Classification of Diseases, 10th Revision) of California residents is the most relevant, bottom-line index for studying the mortality impacts of California's GDL for reasons stated in the Introduction. Further, as its stated purpose, the "graduated drivers license law is aimed at reducing the amount of teen auto injuries and fatalities" (Department of Motor Vehicles, 2013; see Appendix). This goal was to be accomplished both by preventing unsupervised driving by those under age 18 and by creating better drivers through a lengthier licensing system.

However, as a contrasting measure, FARS (2013) tabulations of 35,579 California resident drivers in the 16-39 age group involved in fatal crashes by age are presented for the 1996-2008 period. This supplemental measure is chosen to examine driver experience separately from overall motor vehicle fatality experience among GDL-exposed age groups. The fraction of cases reported as age "unknown" is apportioned to known ages. The California Department of Finance's Demographic Research Unit (2012) provides annual estimates and projections of the state's population by age and year used to calculate fatality rates.

Age Groups

The time period chosen allows for analysis of a test group consisting of ages 16-25, the largest age group available for 1996-2008 that has both pre-GDL and post-GDL experience. The choice of a control series attempts to strike a balance

between employing a group of California residents that is old enough to be completely unaffected by GDL, that is large enough to serve as a stable measure of non-GDL influences on traffic risks and trends, and is close enough in age to the test series (the 16-25 age group) to be influenced by similar factors such as economic cycles, new traffic laws, and weather. Age 26 is excluded due to having contained a subpopulation that, in the last half of 2008, had been subjected to GDL. The control series used here is the youngest age that is too old to have been subjected to GDL through 2008, 27, through age 39.

The choice of the 27-39 age group as a control series for the 18-25 age group is not ideal; there is no ideal control group for traffic fatality analysis that corresponds exactly to the test group. For example, most previous studies used age 18, or the 18-19 or 18-20 age groups, as a control group to assess GDL impacts on the 16-17 age group even though young adults age 18 and older experience considerably different driving influences and environments than high-schoolers. Worse, young adults may suffer higher numbers of accidents and mortalities associated with GDLs (see Masten, Foss, & Marshall, 2011), making the fatal crash trends among 16-17 age groups being tested for GDL effects look more favorable in comparison. That is, using just-older motorists as the control group introduces serious Type I error: it makes a hypothesis of relative GDL benefits for the 16-17 age group easier to attain.

An opposite source of error applies to using ages 27-39 as the control group. In general, the 27-39 age group is economically better off, with higher incomes and lower unemployment rates than the 18-25 age group. That leads to the expectation that the 27-39 age group would be less affected by economic downturns, would drive more during such unfavorable cycles, and consequently would suffer more crash involvements and traffic fatalities. This problem is partially addressed by excluding the years 2009 and later, when a severe economic downturn occurred. However, to the extent that their higher economic status might independently boost traffic crashes and fatalities

Table 1**Average Annual Motor Vehicle Fatality, Driver Fatal Crash Involvement, and Population Counts, Pre-GDL and Post GDL Periods, California Residents, 1996-2008**

Pre-GDL and Post-GDL Periods, California Residents, 1996-2008							
Test series, average annual:					Control series, average annual:		
Age	Period	Fatalities	Crashes	Population	Fatalities	Crashes	Population
Pre-GDL period							
16	1996-1997	71.0	70.0	469,245	845.0	1,485.0	7,028,006
17	1996-1998	79.7	100.3	464,511	808.7	1,440.7	7,048,146
18	1996-1999	104.8	150.5	465,998	802.5	1,412.3	7,066,383
19	1996-2000	105.2	145.8	468,246	789.4	1,401.8	7,079,074
20	1996-2001	101.8	143.2	472,539	796.3	1,408.2	7,080,143
21	1996-2002	102.4	155.3	479,756	799.7	1,411.3	7,072,466
22	1996-2003	97.9	138.5	484,499	807.6	1,406.4	7,059,984
23	1996-2004	84.8	132.6	487,327	818.7	1,412.3	7,042,373
24	1996-2005	81.8	123.1	492,149	823.9	1,408.7	7,019,528
25	1996-2006	80.9	125.0	501,048	820.4	1,404.3	6,996,478
16-17		150.7	170.3	933,756	826.8	1,462.8	7,038,076
18-19		210.0	296.3	934,244	796.0	1,407.0	7,072,728
20-21		204.3	298.5	952,295	798.0	1,409.7	7,076,304
22-23		182.7	271.1	971,826	813.1	1,409.4	7,051,179
<u>24-25</u>		<u>162.7</u>	<u>248.1</u>	<u>993,197</u>	<u>822.1</u>	<u>1,406.5</u>	<u>7,008,003</u>
16-25		910.2	1,284.2	4,785,318	811.2	1,419.1	7,049,258
Post-GDL period							
16	1999-2008	60.6	49.9	521,750	809.9	1,362.8	6,938,998
17	2000-2008	87.6	94.2	521,877	812.8	1,366.8	6,918,765
18	2001-2008	132.4	170.1	529,212	822.3	1,367.6	6,892,381
19	2002-2008	135.3	182.3	534,288	821.0	1,357.3	6,864,795
20	2003-2008	121.5	170.0	541,532	821.2	1,345.2	6,837,860
21	2004-2008	138.4	182.6	542,569	812.8	1,339.8	6,810,909
22	2005-2008	126.3	164.5	542,648	789.3	1,309.8	6,788,266
23	2006-2008	103.3	149.7	537,495	762.0	1,287.7	6,779,715
24	2007-2008	109.5	151.0	540,683	750.5	1,251.5	6,786,581
25	2008	79.0	124.0	545,560	694.0	1,187.0	6,807,135
16-17		148.2	144.1	1,043,627	811.3	1,364.8	6,928,882
18-19		267.7	352.4	1,063,500	821.6	1,362.5	6,878,588
20-21		259.9	352.6	1,084,101	817.0	1,342.5	6,824,385
22-23		229.6	314.2	1,080,143	775.6	1,298.7	6,783,991
<u>24-25</u>		<u>188.5</u>	<u>275.0</u>	<u>1,086,244</u>	<u>722.3</u>	<u>1,219.3</u>	<u>6,796,858</u>
16-25		1,093.8	1,438.3	5,357,615	789.6	1,317.5	6,842,541

for the 27-39 age group more than for the 18-25 age group, the result would be to introduce a more conservative Type II error. That is, the choice of this control group tends to make the hypothesis that GDLs increase traffic risks for the 18-25 age group more difficult to attain.

Analysis of motor vehicle mortality statistics

The hypothesis to be tested by controlled time-

series analysis is whether California's 1998 GDL law was followed by significantly increased motor vehicle fatalities and fatal crash involvements among those ages 16-25 who were exposed to the law. The outcome of interest is operationalized as motor vehicle fatality and driver fatal crash involvement Incidence Rates (IRs) involving California residents during the study period, 1996-2008. CHS vital statistics,

Table 2**Raw Incidence Rates, Average Annual Motor Vehicle Fatalities and Driver Involvement in Fatal Crashes, by Age, Post-GDL vs. Pre-GDL Periods, California Residents, 1996-2008**

Age	Fatality IRs		Fatal crash IRs		Change, post- v. pre-GDL	
	Pre-GDL	Post-GDL	Pre-GDL	Post-GDL	Fatality	Fatal crash
Test series, ages 16-28, Incidence Rates (IRs) per 100,000 population						
16	15.1	14.9	11.6	9.6	0.77	0.64
17	17.2	21.6	16.8	18.1	0.98	0.84
18	22.5	32.3	25.0	32.1	1.11	1.00
19	22.5	31.1	25.3	34.1	1.13	1.10
20	21.6	30.3	22.4	31.4	1.04	1.04
21	21.4	32.4	25.5	33.7	1.19	1.04
22	20.2	28.6	23.3	30.3	1.15	1.06
23	17.4	27.2	19.2	27.8	1.11	1.02
24	16.6	25.0	20.3	27.9	1.22	1.12
25	16.1	24.9	14.5	22.7	0.90	0.91
16-17	16.1	18.2	14.2	13.8	0.88	0.76
18-19	22.5	31.7	25.2	33.1	1.12	1.04
20-21	21.4	31.3	24.0	32.5	1.12	1.04
22-23	18.8	27.9	21.3	29.1	1.13	1.04
<u>24-25</u>	<u>16.4</u>	<u>25.0</u>	<u>17.4</u>	<u>25.3</u>	<u>1.06</u>	<u>1.01</u>
16-25	19.0	26.8	20.4	26.8	1.07	1.00
Control series, ages 27-39, Incidence Rates (IRs) during corresponding period, to age:						
16	12.0	21.1	11.7	19.6	0.97	0.93
17	11.5	20.4	11.7	19.8	1.02	0.97
18	11.4	20.0	11.9	19.8	1.05	0.99
19	11.2	19.8	12.0	19.8	1.07	1.00
20	11.2	19.9	12.0	19.7	1.07	0.99
21	11.3	20.0	11.9	19.7	1.06	0.99
22	11.4	19.9	11.6	19.3	1.02	0.97
23	11.6	20.1	11.2	19.0	0.97	0.95
24	11.7	20.1	11.1	18.4	0.94	0.92
25	11.7	20.1	10.2	17.4	0.87	0.87
16-17	11.7	20.8	11.7	19.7	1.00	0.95
18-19	11.3	19.9	11.9	19.8	1.06	1.00
20-21	11.3	19.9	12.0	19.7	1.06	0.99
22-23	11.5	20.0	11.4	19.1	0.99	0.96
<u>24-25</u>	<u>11.7</u>	<u>20.1</u>	<u>10.6</u>	<u>17.9</u>	<u>0.91</u>	<u>0.89</u>
16-25	11.5	20.1	11.5	19.3	1.00	0.96

Note: The IR (Incidence Rate) is motor vehicle fatalities and driver fatal crash involvements per 100,000 population.

FARS driver involvement, and Department of Finance population data are used to calculate residents' motor vehicle fatality and driver fatal crash involvement IRs per 100,000 for single-year ages 16 through 25 and for the 27-39 age group in aggregate for each calendar year, 1996 through 2008. Each age and age group is divided

into prelaw and postlaw cohorts according to when they were subject to the requirements of California's GDL law.

The prelaw cohort in this analysis consists of a control series of persons who died in traffic accidents in each calendar year, beginning with

Table 3**Comparative Crude Motor Vehicle Fatality Incidence Rate Ratios (IRRs) and Adjusted IRRs Among California's Pre- and Post-GDL populations, 1996-2008**

Age	Motor vehicle fatality IRRs			Driver fatal crash IRRs		
	Young drivers adjusted by control series			Young drivers adjusted by control series		
	<u>Pre-GDL</u>	<u>Post-GDL</u>	<u>Adjusted IRR</u>	<u>Pre-GDL</u>	<u>Post-GDL</u>	<u>Adjusted IRR</u>
16	1.26	1.00	0.79 (0.71-0.87)	0.71	0.49	0.69 (0.60-0.78)
17	1.49	1.43	0.96 (0.88-1.03)	1.06	0.91	0.86 (0.80-0.93)
18	1.98	2.10	1.06 (0.99-1.12)	1.62	1.62	1.00 (0.95-1.06)
19	2.01	2.12	1.05 (0.98-1.12)	1.57	1.73	1.10 (1.04-1.16)
20	1.92	1.87	0.98 (0.88-1.07)	1.52	1.60	1.05 (0.98-1.11)
21	1.89	2.14	1.13 (1.05-1.21)	1.62	1.71	1.05 (0.99-1.12)
22	1.77	2.00	1.13 (1.04-1.23)	1.44	1.57	1.09 (1.01-1.18)
23	1.50	1.71	1.14 (1.02-1.26)	1.36	1.47	1.08 (0.98-1.18)
24	1.42	1.83	1.29 (1.15-1.44)	1.25	1.51	1.22 (1.10-1.33)
25	1.38	1.42	1.03 (0.80-1.26)	1.24	1.30	1.05 (0.86-1.23)
16-17	1.37	1.21	0.88 (0.83-0.94)	0.88	0.70	0.80 (0.74-0.85)
18-19	2.00	2.11	1.06 (1.01-1.10)	1.59	1.67	1.05 (1.01-1.09)
20-21	1.90	2.00	1.05 (1.00-1.11)	1.57	1.65	1.05 (1.00-1.10)
22-23	1.63	1.86	1.14 (1.07-1.21)	1.40	1.52	1.09 (1.03-1.15)
<u>24-25</u>	<u>1.40</u>	<u>1.63</u>	<u>1.17 (1.05-1.29)</u>	<u>1.24</u>	<u>1.41</u>	<u>1.13 (1.03-1.23)</u>
16-25	1.65	1.77	1.07 (1.04-1.10)	1.33	1.39	1.05 (1.02-1.07)

Note: The IRR is the IR for each age group in the test series adjusted by the IR of control series, age 27-39, for the corresponding time period. The Adjusted IRR is the IRR for each age group in the post-GDL series is adjusted by the corresponding IRR for the pre-GDL series.

1996, through the year before their age first was subjected to GDL requirements. The postlaw cohort consists of a test series of persons who died in traffic crashes beginning in the calendar year after the date their age first was subjected to the GDL law through 2008. Crashes occurring in the intervening calendar year in which each age was first subjected to the GDL law are not included for that age (see Males, 2007). The law first applied to 16-year-olds on July 1, 1998, and would first have affected each older age group on July 1 of subsequent years. Therefore, the pre-GDL period for age 16 is 1996 through 1997, the GDL year of 1998 is excluded, and the post-GDL period is 1999 through 2008. The analysis is repeated for drivers involved in fatal crashes. Table 1 shows motor vehicle fatality and population counts, IRs, and IRRs by age and time periods used in the analysis.

Traffic fatality and fatal crash involvement rates may be strongly affected by non-GDL factors, such as changes in seat belt, drunken driving,

and other traffic safety laws, economic cycles, fuel prices, weather conditions, and other contingencies that affect all age groups. Thus, motor vehicle fatality IRs are calculated for the control series, the 27-39 age group for corresponding time periods, and these are used to adjust test series fatality IRs, yielding Incident Rate Ratios (IRRs) for each age and year.

Table 2 shows the IRs produced from the fatality and population counts shown in Table 1 summed over the pre-GDL and post-GDL periods, along with the post-GDL versus pre-GDL changes in IRs. Table 3 shows the Incidence Rate Ratios (IRRs), which express the motor vehicle fatality IRs for each test age subjected to GDL compared to those of the control series. An IRR of greater than 1.00 indicates the test age has a higher risk of fatality than corresponding control series' risk.

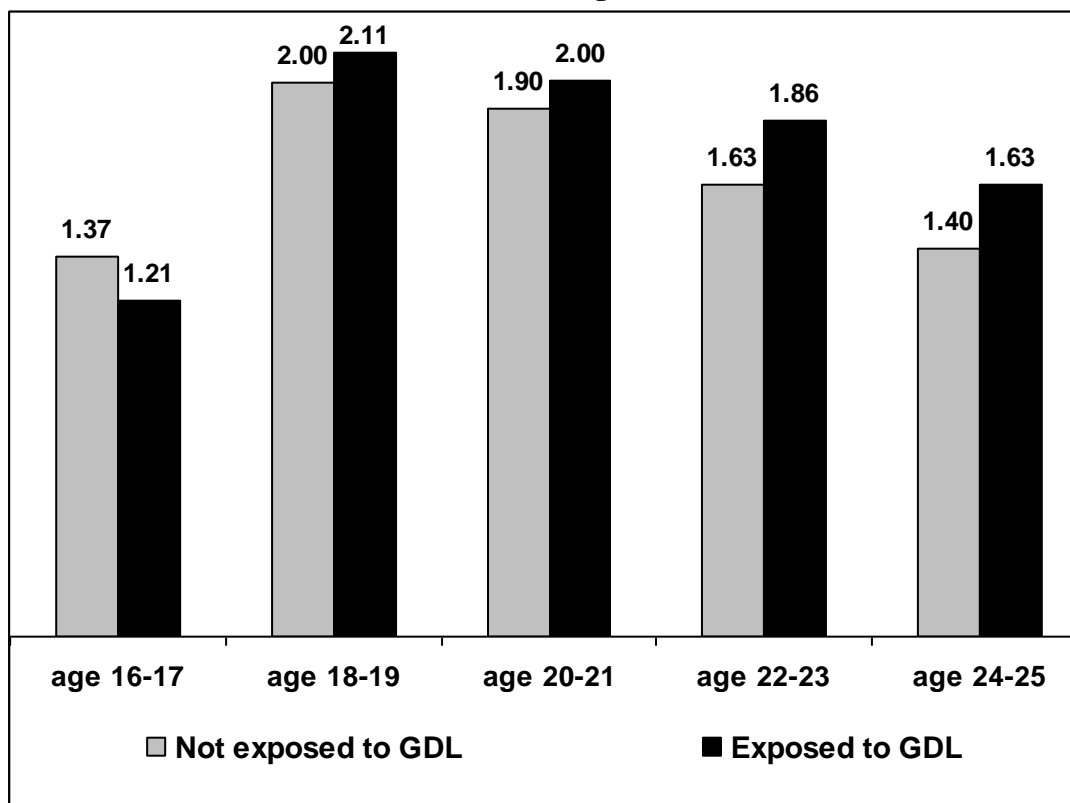
Finally, Table 3 compares the IRRs for postlaw versus prelaw subcohorts to produce the

Adjusted IRRs, which express the difference in the test ages' IRRs from the pre-GDL to the post-GDL periods. The Adjusted IRR shows the net effect associated with the GDL on motor vehicle deaths and driver crash involvements. An Adjusted IRR of more than 1.00 means that a test-age IRR relative to the corresponding control series IRR is higher in the post-GDL period than in the prelaw period, indicating the

GDL law is associated with an increase in test-age fatalities or driver crash involvements. Confidence Intervals and statistical significance are calculated from the summed, post-GDL versus pre-GDL fatality and population totals and IRs for the test groups compared to the control groups (see Rothman & Greenland, 2008). An Adjusted IRR is statistically significant if its Confidence Interval (CI, also shown) does not contain 1.00.

Figure 1

Motor Vehicle Fatality Incidence Rate Ratio (Relative to Control Series) by Aggregated Ages, Before Versus After that Age Was Exposed to Graduated Driver Licensing



Results

Of the single ages exposed to the GDL, three showed decreases in motor vehicle fatalities (one of which, age 16, was significant), and seven showed increases (four, ages 21-24, were significant) (Table 3). For aggregated ages, the 16-17 age group had a significant, 12% fatality decrease after GDL, while significant fatality increased occurred among the aggregated 18-19

(6%), 20-21 (5%), 22-23 (14%), and 24-25

(17%) age groups. The entire 16-25 age group exposed to GDL suffered a significant, 7% increase (95% CI, 4% to 10%) in motor vehicle fatalities over their aggregated 55 age-years of post-GDL experience. The IRR for this age group relative to the control age increased from 1.65 prior to GDL to 1.77 after; that is, the 16-25 age group were 65% more likely than the older

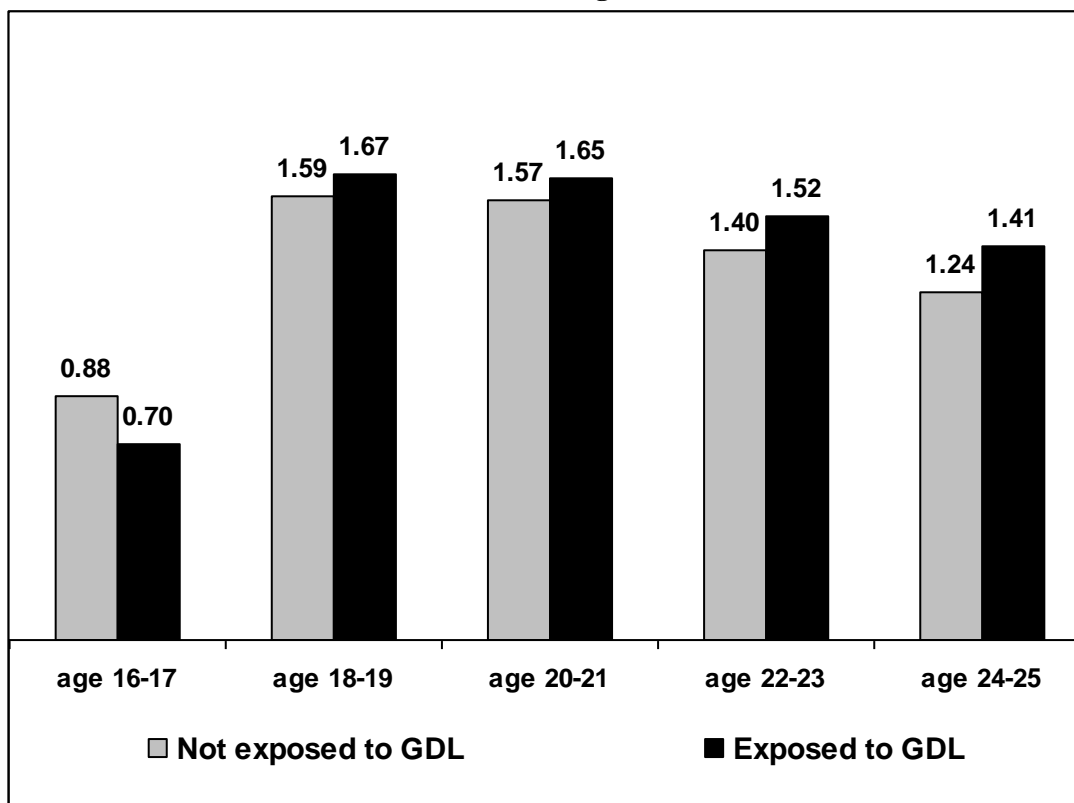
control ages to suffer traffic fatality prior to GDL, and 77% more likely after being exposed to GDL.

The analysis of FARS driver involvement data for the same period yielded a similar result. Two ages showed decreases in fatal involvements (16 and 17, both significant). Eight ages showed increases; three were significant (ages 19, 22, and 24). The 16-17 age group showed a

significant 20% decrease in driver fatal crash involvements after GDL, while significant increases occurred for the 18-19 (5%), 20-21 (5%), 22-23 (9%), and 24-25 (13%) age groups. Overall, drivers in the 16-25 age group showed a significant 5% increase in drivers' fatal crash involvements after the GDL took effect (95% CI, 2% to 7%), with adjusted IRRs relative to control series drivers rising from 1.33 before GDL exposure to 1.39 after.

Figure 2

Drivers Involved in Fatal Crashes, Incidence Rate Ratio (Relative to Control Series) by Aggregated Ages, Before Versus After that Age Was Exposed to Graduated Driver Licensing



Figures 1 and 2 illustrate the “see-saw” effects of GDL on the 16-17 age group (decreased fatalities and fatal crash involvements) versus older age groups (increased fatalities and fatal crash involvements) derived by comparing the motor vehicle fatality IRRs for the GDL-exposed cohorts versus cohorts not exposed to

GDL relative to the control series over corresponding time periods.

California’s GDL law is associated with an average of 34 (95% CI= 25 to 44) fewer driver fatal crash involvements and 18 (95% CI= 9 to 26) fewer traffic fatalities among the 16-17 age

group annually. These are offset by 91 (95% CI= 65 to 117) more driver fatal crash involvements and 81 (95% CI= 61 to 101) more traffic deaths among GDL-exposed 18-25 year-olds age group every year. Overall, young, GDL-exposed ages experienced a net of approximately 59 more driver involvements in fatal crashes and 64 motor vehicle fatalities per year in the 16 through age 25 age group than would be predicted from the same ages not exposed to the GDL law.

Discussion

Assessment of California's Graduated Driver Licensing law through 2008, 10 years after it first took effect, for age groups nine years older than those first exposed to the law in 1998, finds mostly negative effects. The reductions in traffic crashes and fatalities GDL brings among 16-17 year olds is more than offset by increased crashes and fatalities among young adult drivers previously exposed to GDL. This study is not the first to find such a result, but it does suggest that the hazards of GDL "graduates" extend beyond late teen years and well into the twenties. These findings also suggest previous research that had found beneficial effects of GDL may have been premature and limited, in that they failed to assess effects on young-adult GDL "graduates" and failed to incorporate measures broader than just driver crash involvements.

Still, from a logical standpoint, how could a GDL law affecting 16- and 17-year-olds still be influencing motor vehicle fatalities among motorists a nearly a decade older and later? These results would be difficult to explain under conventional theories that teenagers, due to cognitive and developmental deficiencies, are not like adults (Dobbs, 2011; Insurance Institute for Highway Safety, 2012). If teenaged traffic risks are innate to that age, we would expect drivers in their twenties to have "aged out" of their risk-prone years and to be relatively unaffected by any holdover effects of the GDL law they experienced several years in the past. Therefore, an alternative theory sketched in previous papers (Males, 2010, 2007, 2006) is offered to explain this paradox.

Under the alternative theory, higher teenage and young-adult motor vehicle fatality risks (as measured by fatality incidence) result not from their innate cognitive or maturity deficiencies, but from their lack of driving experience (Traffic Injury Research Foundation, 2008) and low socioeconomic status (see Males, 2010). These factors are interrelated, in that younger people tend to have higher poverty and lower income levels than older people, and low-income individuals tend to drive less than higher-income ones. More than any other, the effect of GDL is to prevent 16- and many 17-year-olds from driving, and to require them to drive under artificial conditions of adult supervision, peer passenger restrictions, and nighttime driving restrictions. That is, GDL hampers young drivers from obtaining independent experience with a variety of driving challenges at younger ages, creating tasks that must be learned at later ages.

When other factors are neutralized (as by the Incidence Rate Ratios shown in Table 3 and Figures 1, 2), young-adult GDL "graduates" in 21 and older age groups appear to suffer higher traffic fatality and driver fatal crash involvement levels previously characteristic of those around two years younger. That is, the 20-21 age group exposed to GDL has traffic fatality IRRs (2.00) like those of the 18-19 age group not exposed to GDL (2.00); the post-GDL 22-23 age group has IRRs (1.86) similar to those of the pre-GDL 20-21 age group (1.90); and the post-GDL 24-25 age group has IRRs identical to those of the pre-GDL 22-23 age group (1.63). What does this pattern suggest? If more driving experience—including driving independently, at night, and with passengers—is one key to greater driving safety, then the chief effect of GDL is to delay the acquisition of driving skills in the 16-17 age group, who then must acquire them at ages 18 and older. If this is the case, California's GDL should simply be repealed; extending it to young adults would compound its negative effects on young adults.

An ancillary theory is that the association of GDL with more young-adult traffic hazards results from deputizing all parent and nearby licensed drivers age 25 and older as driving

instructors for new under-18 licensees. In a larger sense, GDL is part of a long-term shift toward making private entities (in this case, family and nearby adults) responsible for providing services that were once provided publicly (in this case, driver education in high schools, which mostly has been eliminated in California). The problem with making driver training a family responsibility is that bad parent drivers tend to have teenagers who are bad drivers (Taubman-Ben-Ari, Mikulincer & Gillath, 2005; Bianchi & Summala, 2004). When faulty adult drivers instruct new teen drivers, bad habits may become entrenched and persist well past teen years.

This suggests that California's GDL should be replaced by a system requiring enhanced professional driving instruction and certification (ADTSEA, 2006) as a condition of licensing new drivers regardless of age. Because professional driver training is more expensive than the cheaper tactic of simply designating any over-25 parent or other adult as a driving instructor, a sliding fee scale or subsidy would be needed to reduce the impact on low-income licensees.

Finally, consistent findings of higher risk in post-GDL cohorts indicate that studies that employ control series of just-older young adults containing subpopulations previously exposed to GDL (i.e., Fell et al, 2011; Chen, Baker & Li, 2006) have exaggerated fatality reductions among the 16-17 age group and should not be accepted as comprehensive evaluations of the full range of GDL effects (see Masten & Hagge, 2003). Driver crash involvement outcome measures should be supplemented with measures that capture passenger and non-vehicle-occupant experiences, which are also consequences of GDL laws. Unfortunately, the type of study using faulty control groups and limited measures constitutes the great bulk of the literature used to recommend GDL to policy makers at the state and national levels.

Limitations

The findings and recommendations of this study apply only to California, not to the other 48 states that have implemented 48 different kinds

of GDL laws and different times and require their own separate analyses. Further, there are general difficulties inherent in studying GDL. The ideal study would compare the traffic risk experiences of teenage and adult motorists known to have experienced the graduated system to a random sample of those of identical ages, time periods, locales, and circumstances who did not experience GDL. Current law structures and data sets do not allow such a comparison. To the extent this study has employed alternatives, such as a test sample that includes an unknown number of drivers who may have immigrated to the state after age 18, or the 27-39 year-old control group, they have been ones that would make the hypothesis of greater risk to young adult drivers more difficult to prove and therefore make the findings here more robust.

Conclusion

California's 1998 Graduated Driver Licensing Law, evaluated using traffic mortality and driver crash involvement statistics for the 1996-2008 period, is associated with reduced motor vehicle fatalities and crash involvements among the 16-17 age group but increased fatality risks among young-adult GDL "graduates." Young adults in 20 and older age groups who were exposed to GDL as teenagers display traffic fatality levels similar to younger motorists who were not exposed to GDL, indicating that GDL may subject young drivers to unnecessary delays and restrictions and inadequate driver training, effectively delaying them by around two years in obtaining necessary driving experience.

California's young people were safer and better trained under the state's old, simple driver licensing law, which was associated with dramatic declines in teenage and young-adult traffic fatalities, than under the new GDL. Rather than dictating lengthy and complicated procedures applied to all new 16-17 year-old applicants, the old law allowed families and teenagers to tailor their learning experience to individual characteristics and circumstances. GDL's success in reducing fatalities among 16-17 year-olds is due not to better training, but to simply forcing many that age off the road. Preventing 16-17-year-olds from obtaining

independent driving experience extracts a heavy price among young adults, who must then acquire that experience under more hazardous circumstances. A 2009 legislative bill to address these problems with GDL by extending some graduated requirements to new 18- and 19-year-old licensees (which failed to win approval)

appears to be the wrong approach. Rather than measures to universalize, extend, or strengthen GDL, the new situation is best termed as “back to the drawing board” toward a simpler, more flexible, and professionally-directed driver licensing framework.

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Appendix A

California Graduated Driver's License (GDL) (California Department of Motor Vehicles, 2013)

In July 1998, California enacted a new law that requires all new teen drivers to obtain drivers licenses through a three-step process. This graduated driver's license law is aimed at reducing the amount of teen auto injuries and fatalities as statistics show that drivers between the ages of 15 and 19 experience a very high number of collisions.

California teens are first required to go through a supervised period (with a learners permit) during which time the teen must complete 50 hours of supervised driving. Ten of the required hours must be performed at night. A parent or guardian is responsible for certifying in writing that the proper number of hours has been completed.

The student must also comply with the following restrictions:

- The student is only allowed to drive with a parent or guardian, an adult over 25 years of age, or with a licensed professional instructor. All supervising drivers must have a current California driver's license.
- New drivers must enroll in and complete at least 6 hours of a driver's training course.
- He or she must keep a clean driving record.
- The Zero Tolerance law applies until you turn 21. This means that student may not drink and drive.
- Effective July 1, 2008, a new law will ban the use of cell-phones (with or without hands-free devices), laptops, pagers, and other electronic devices by anyone under 18 who is driving.

Once the teen has successfully completed the first step, he or she is free to move on to the next stage. In step two, the student may receive a provisional license if he or she is between 16 and 18 years old and has passed a behind-the-wheel driving test. The new driver must also provide a parent's signature on his or her instruction permit stating that he or she has completed all required driving practice.

With a provisional license, the new driver is required to abide by the following regulations:

- For the first 12 months (or until the driver reaches his or her 18th birthday), no passengers under the age of 20 are allowed in the provisional license holder's vehicle unless a licensed driver age 25 or older is present.
- For the first 12 months, the new driver needs to be accompanied by a driver 25 years of age or older if teenager is driving between the hours of 11 P.M. and 5 A.M. or if the driver is transporting passengers under the age of 20.

A full-privilege license may be granted after the driver successfully undergoes the first two steps for the proper amount of time and there are no outstanding DMV or court-ordered restrictions, suspensions, or probations on the driver's record.